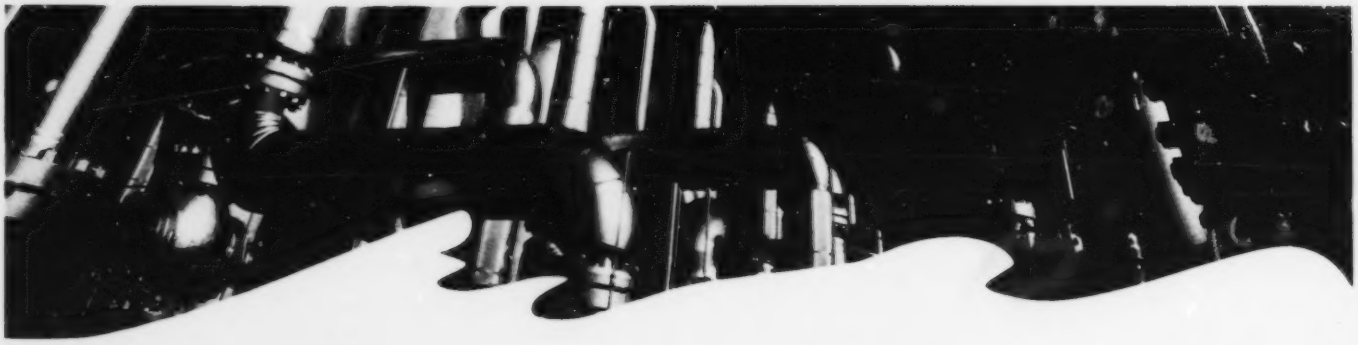

St. Lawrence TECHNOLOGIES

ABSTRACT

Contaminated sediment must be characterized and managed by means of rapid and economical assessment methods in order to prevent any adverse impacts on the environment. Bioassays are now being conducted to complement physico-chemical analyses because they take into account both the potential toxicity of mixtures of contaminants and their bioavailability. However, there are very few standardized assays for the assessment of sediment toxicity, and new screening tools must be developed to facilitate sediment management in freshwater environments. The aim of this project was to determine the applicability of 20 different microbioassays to measure the toxic potential of freshwater sediments.

Saint-Laurent Vision 2000

CONTAMINATED SEDIMENT

DEVELOPMENT AND VALIDATION OF TOXICITY SCREENING ASSAYS FOR FRESHWATER SEDIMENTS

MAIN FEATURES

- **Technology**
  - Easy-to-use microbioanalytic techniques
  - Rapid, reliable and easy-to-interpret results
  - Bioanalytic performance enhanced by miniaturized assays.
- **Ecotoxicology**
  - Measures lethal and sublethal toxicity thresholds, and genotoxic potential of freshwater sediment
  - Microbioassays representative of the different trophic levels of the aquatic ecosystem.
- **Cost**
  - Low sample volume needed for analyses
  - Modest laboratory space and equipment requirements
  - More cost-effective than macro-scale bioassays.

Environnement Canada Protection Région du Québec

Environment Canada Protection Québec Region

beak

ebpi environmental bio-detection products inc.

Federal Office of Regional Development (Québec)

Bureau fédéral de Développement régional (Québec)

BACKGROUND

New tools are needed to assess the impacts of the maintenance and development activities associated with shipping. Those charged with the management of contaminated sediments must have recourse to microbioassays that are both reliable and representative of the toxic potential of sediments; simplicity, rapidity and low cost will encourage their use. The bioanalytical information gleaned from such assays will facilitate decision making as to the dredging and disposal of contamined sediment or its treatment.

TECHNOLOGY

Twenty microbioassays, coupled with physico-chemical analyses and benthic surveys, were done on over 15 samples of sediments contaminated to varying degrees. The sediments were sampled three times in various sectors of the St. Lawrence River, notably in the Port of Montreal region, near Sorel, and in Lakes Saint-François and Saint-Louis. Depending on their characteristics, the bioassays were applied to three sediment components: whole sediments, interstitial water, and organic extracts. The different analyses performed by Beak International, Environmental Bio-Detection Products (EBPI), and the St. Lawrence Centre (SLC) of Environment Canada are shown in Figure 1.

WHOLE SEDIMENT

Toxicity Assay

BEAK
- Survival and growth using *C. riparius*
- Survival and growth using *H. azteca*
- In situ ATP assay on micro-organisms
- Solid-phase assays using the luminescent bacterium *V. fischeri*

EBPI
- Direct-contact SOS Chromotest™
- ToxiChromoPad™

SLC
- Solid-phase algal assay

PHYSICO-CHEMICAL ANALYSES

Metals with simultaneous extraction of acid-volatile sulphides • PAHS • PCBs • Mineral oils and greases • Total organic carbon • Particle size distribution

INTERSTITIAL WATER

Toxicity Assay

BEAK
- Thamnotoxkit F™
- Rotoxkit F™
- Daphtoxkit™
- Algaltoxkit™
- Daphnia IQ™
- Assay using the luminescent bacterium *V. fischeri*
- Mutatox™

EBPI
- SOS Chromotest™
- MutaChromoPlate™

SLC
- Growth inhibition of the alga *S. capricornutum*
- Assay with the hydra *H. attenuata*
- Chronic assay using the luminescent bacterium *V. fischeri*
- Microplate assay using the luminescent bacterium *V. fischeri*
- Hepatocellular model with measurement of viability, MFO (mixed function oxidase), metallothioneins, and DNA damage
- Algal assay measuring esterase inhibition

CHEMICAL ANALYSES

Ammonia • Dissolved organic carbon • PAHS • PCBs • Metals (with simultaneous extraction of acid-volatile sulphides)

ORGANIC EXTRACTS

Toxicity Assay

BEAK
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- Chronic assay using the luminescent bacterium *V. fischeri*

104-01531/

RESULTS

Several qualitative and quantitative criteria were established to assess the performance and the usefulness of microbioassays (Table 1). The results of both the bioassays and the physico-chemical analyses were examined to establish a correlation between bioassays and contaminant concentrations, determine the toxicity to benthic invertebrates, and establish which natural substances could cause intrinsic toxicity (e.g., ammonia). An index of general performance was assigned to each bioassay by adding together points scored for each criterion.

Table 2 shows which microscale screening assays scored highest in their respective categories (i.e., as a function of trophic level). The adenosine triphosphate (ATP) test, the solid-phase algal assay using *Selenastrum capricorutum*, the hydra assay, the Thamnotoxkit F™, and the SOS Chromotest were among the most promising and innovative assays.

This research project demonstrated the usefulness of bioassays using organic sediment extracts. The results obtained to date have shown a correlation between responses recorded using these extracts and responses obtained with conventional tests on whole sediments. Moreover, in certain cases, the use of organic extracts eliminates those factors which could falsify the interpretation of results (e.g., ammonia), and it allows for the concentration of extracts, thus removing the lack of sensitivity of organisms as a limiting factor.

Lastly, our results confirm the importance of taking reference samples of sediments from nearby the study site and which have the same physical (e.g., particle size) and chemical (e.g., organic carbon content) characteristics as the test sediments: the establishment of background noise levels is vital to the interpretation of bioassay results.

Table 1

CRITERION
Speed of execution
Time elapsed between arrival of sample and result
Analytical productivity
Cost of material
Reproducibility
Repeatability
Ecological relevance
Validation
Cost of analytic instruments
Availability of organisms
Correlation with benthic invertebrates
Correlation with contaminants
Correlation with naturally-occurring substances

Table 2

TYPE OF ASSAY (TROPHIC LEVEL)	ASSAY	LIQUID PHASE	SOLID PHASE	LETHALITY	SUBLETHALITY	PERFORMANCE INDEX	REFERENCE
Assay using bacteria	Microplate Microtox	√			√	43	SLC, 1995
	Chronic Microtox	√			√	38	Microbics, 1995
	ATP test		√	√		53	BEAK, 1995
	Solid phase Microtox		√		√	33	Microbics, 1995
	ToxicChromoPad		√		√	43	EBPI, 1995
Assay using phytoplankton	Conventional algal test	√			√	37	EPS 1/RM/25
	Algaltoxkit	√			√	39	Creative Selling, 1996
	Solid phase algal test		√		√	47	SLC, 1995
Assay using invertebrates living in the water column	Test using Hydra (predator)	√		√		42	SLC, 1995
	Thamnotoxkit	√		√		46	Creative Selling, 1995
	Daphtoxkit	√		√		44	Creative Selling, 1996
Genetoxicity assay	SOS Chromotest	√			√	36	EBPI, 1995
	Mutatox	√			√	34	Microbics, 1996
Conventional assay with benthic invertebrates	Chironomids		√	√	√	46	ASTM, 1990 E 1383-90: 1085-1104
	Amphipods		√	√	√	47	EPA/600/4-90/027 F

Note: The composition of a battery of tests also considers other factors such as the effect being considered (lethality versus sublethality) and the matrix tested (interstitial water vs whole sediments), indicated by check marks.

PROJECT OBJECTIVES

The project's primary goal was to study the performance and usefulness of various microbioassays in detecting the toxic potential of sediments from freshwater environments.

More specifically, the objectives were:

1) To evaluate the relative sensitivity of the chosen microbioassays to anthropogenic chemical substances compared to natural-source substances (e.g., ammonia)

2) To determine which microbioassays can best predict the toxicity demonstrated by more lengthy conventional bioassays on benthic invertebrates

3) To evaluate the usefulness of a) the interstitial water component of sediments and b) the organic extract of sediments as support matrices for assessing the toxicity of whole sediments

4) To establish a selection of the most promising bioassays, taking into account both qualitative and quantitative criteria

5) To be able to offer a battery of analytic bioassays for various trophic levels that would meet the demands specific to the management of contaminated sediment.

Phases

A) Preparation of lab set-ups and drafting of standard operating procedures.

B) Preparation of control charts with reference toxicants.

C) First series of bioassays with three components: whole sediments, interstitial water and organic extracts, and preliminary selection.

D) Second series of bioassays with the same three components and selection of the most promising and innovative assays.

E) Validation of microbioassays by means of an interlaboratory calibration exercise.

F) Development of the method for using bioassay and data interpretation methodology.

BACKGROUND

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FIGURE 1: SEDIMENTS

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ASSESSMENT CRITERIA OF MICROBIOASSAYS

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Ecological relevance
Validation
Cost of analytic instruments
Availability of organisms
Correlation with benthic invertebrates
Correlation with contaminants
Correlation with naturally-occurring substances

Table 2

RELATIVE POSITION OF ASSAYS ACCORDING TO DECISION-MAKING MATRIX

TYPE OF ASSAY (TROPHIC LEVEL)	ASSAY	LIQUID PHASE	SOLID PHASE	LETHALITY	SUBLETHALITY	PERFORMANCE INDEX	REFERENCE
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POTENTIAL AND LIMITATIONS

The use of microbioassays to screen and monitor toxicity may prove useful as part of a larger strategy for assessing sediment contamination. By targeting regions where sediment contamination poses a risk to both benthic and aquatic organisms, these assays will serve to optimize sediment- and water-sampling programs at sites where dredging or restoration is planned. These assays could even be applied to the assessment of soil contamination. However, it is worth noting that some tests can be sensitive to naturally-occurring toxic substances, such as ammonia, and that complementary analytic monitoring of these substances is always recommended.

The ecotoxicological assessment of a complex matrix like sediment is a relatively new area. Promising microbioassays were identified in this study, but few of them can be carried out on whole sediments. Research currently under way should help lead to the development of microbioassays to fill this knowledge gap.

INFORMATION

This technology data sheet is based on the results of an ongoing study carried out and financed jointly by the St. Lawrence Centre and the Technology Development Section of Environment Canada, and the firm BEAK International Inc., in collaboration with Environmental Bio-Detection Products Inc.

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St. Lawrence TECHNOLOGIES

St. Lawrence Technologies data sheets are intended for all companies, industries, organizations and individuals interested in new environmental technologies. They are produced by the Technology Development Section, Environment Canada, as part of St. Lawrence Vision 2000. They serve to disseminate the results of technology development and demonstration projects conducted in the following five sectors: industrial wastewater; contaminated soil; hazardous wastes; contaminated sediment and innovative technology.

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Canada

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